Deep Bleeder Acoustic Coagulation (DBAC)

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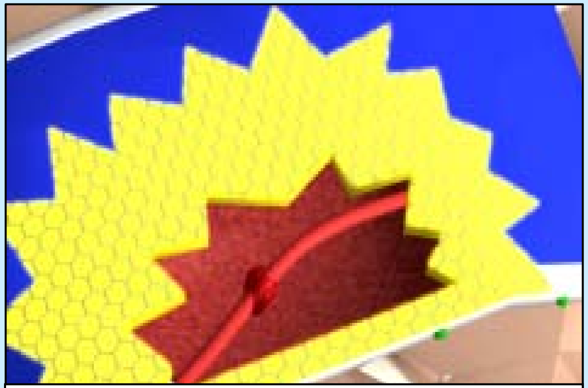
- Program Goal
  - Develop a system capable of locating and coagulating deep internal bleeders using a combination of Doppler ultrasound for location and high powered ultrasound for coagulation that allows untrained soldiers to stop bleeding on the battlefield

Conceptual Implementation of DBAC Device


Ultrasonic cuff is applied


Bleeder location is determined


Coagulation is performed

- Operational Impact
  - Needless combat deaths and amputations that occur today due to the time delay in evacuation to a surgical facility will be prevented by treating the deep bleeders on the battlefield

Program Goal

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  - The overall goal of the DBAC program is to stop bleeding quickly enough to prevent the transition from non-progressive shock to progressive shock, which occurs when the soldier loses 25% of his blood volume
  - The DBAC program will develop a portable, light-weight, non-invasive, automated system for the detection, localization, and coagulation of deep bleeders that is operable by minimally trained personnel in the combat environment
- Phase I
  - Design and build the ultrasound transducer cuff and demonstration at the DBAC testbed
- Phase II
  - Design and development of the detection, localization, and coagulation algorithms
  - Use these algorithms to demonstrate control of the ultrasound transducer cuff developed in Phase I at the DBAC testbed with a human in the loop
- Phase III
  - Automated system that can achieve the program goals without a human in the loop
  - Full system will be demonstrated in vitro and in vivo at the DBAC testbed.

DBAC Notional CONOPS

Notional DBAC Approach

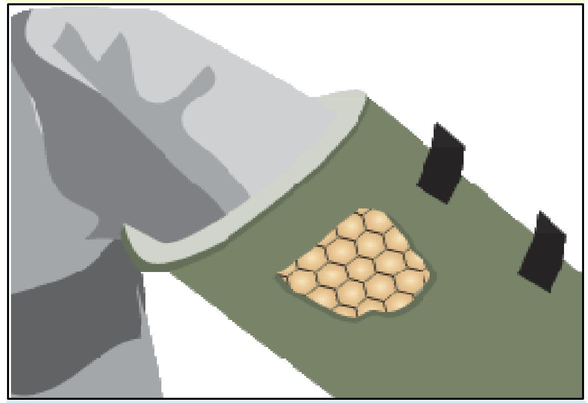
Detect

Area is scanned and bleeder is detected

Detection Steps:

- Scan to detect bleeder by looking for bleeder Doppler signal
- Determine subarrays that detect a Doppler shift

Locate

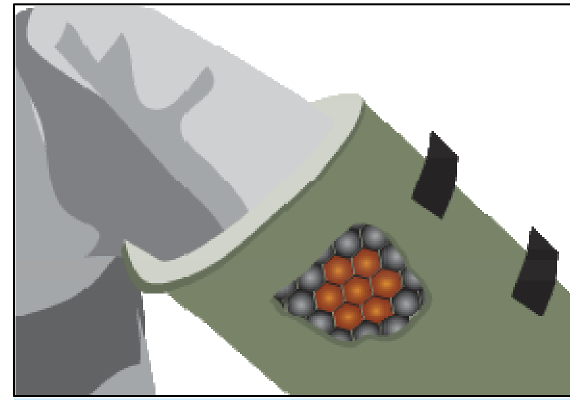


Detected Bleeder is located

Location Steps:

- Optimize targeting of high powered subarrays by auto focusing on Doppler signal

Coagulate



Bleeder is coagulated using high powered ultrasound

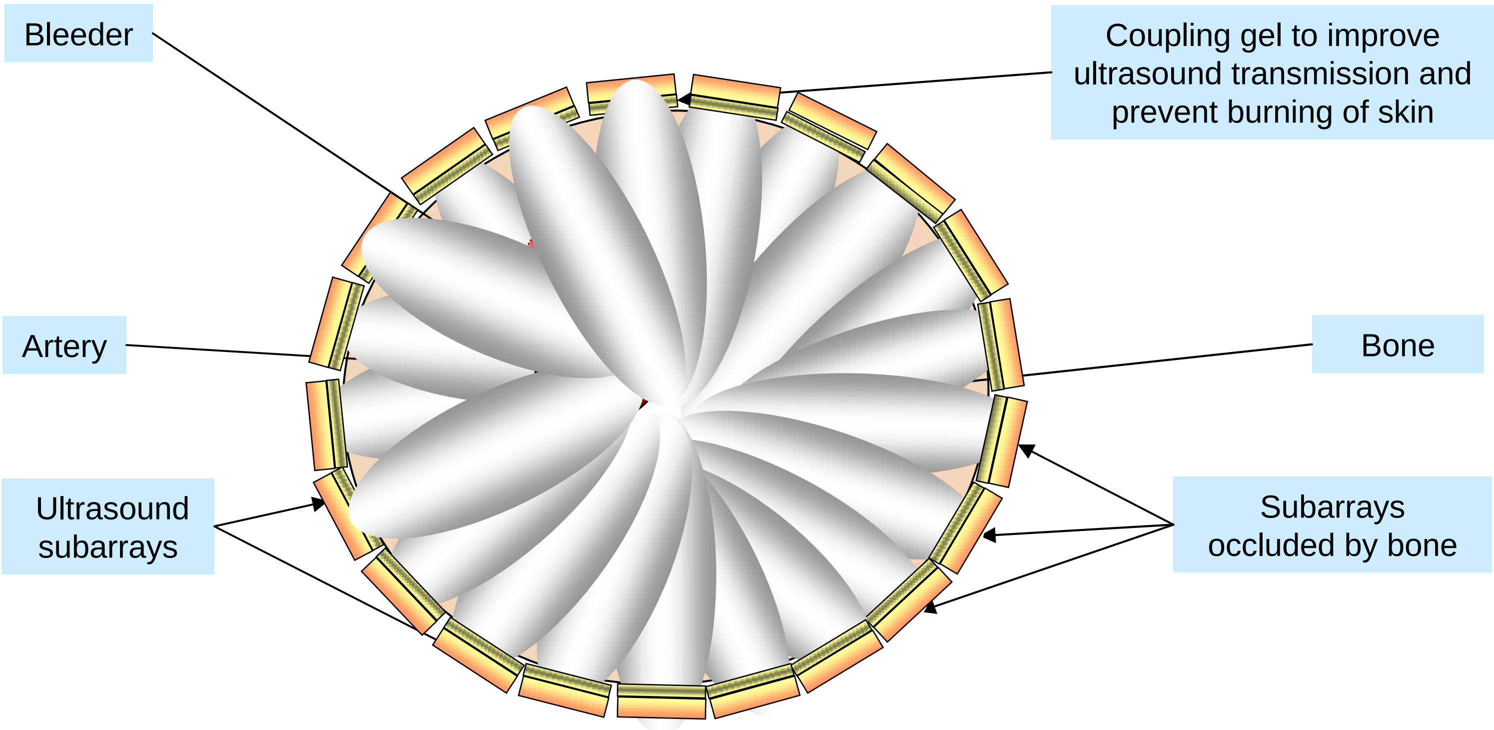
Coagulation Steps:

- Fire transducers at bleeder site using phasing and multiple beams to prevent burning of tissue
- Monitor coagulation progress through decreased Doppler shift

Scanning for Doppler Signature

Detection of Bleeder Using Doppler

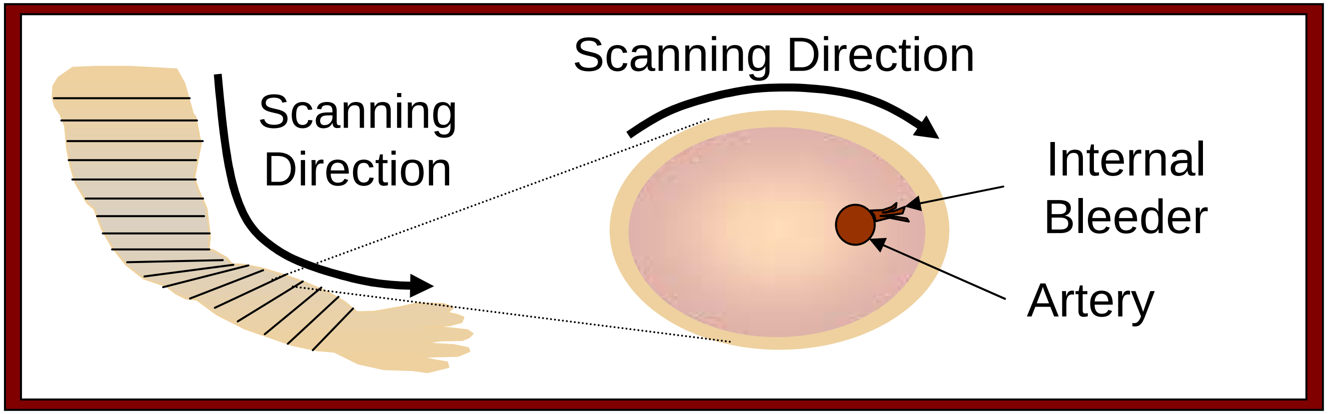
- Initial scanning procedure will utilize all subarrays to look for the Doppler signature of a bleeder



Automated Bleeder Location

Automated Scanning of Bleeder Location

- A conformal array made up of multiple ultrasound transducer subarrays will be wrapped around the treatment area
  - Multiple subarrays are positioned in relation to the bleeder at different angles
  - This angle diversity ensures that at least one subarray will have the proper angle to detect the bleeder
- Subarrays will fire sequentially along the array in an automated manner and listen for the Doppler shift of a bleeder

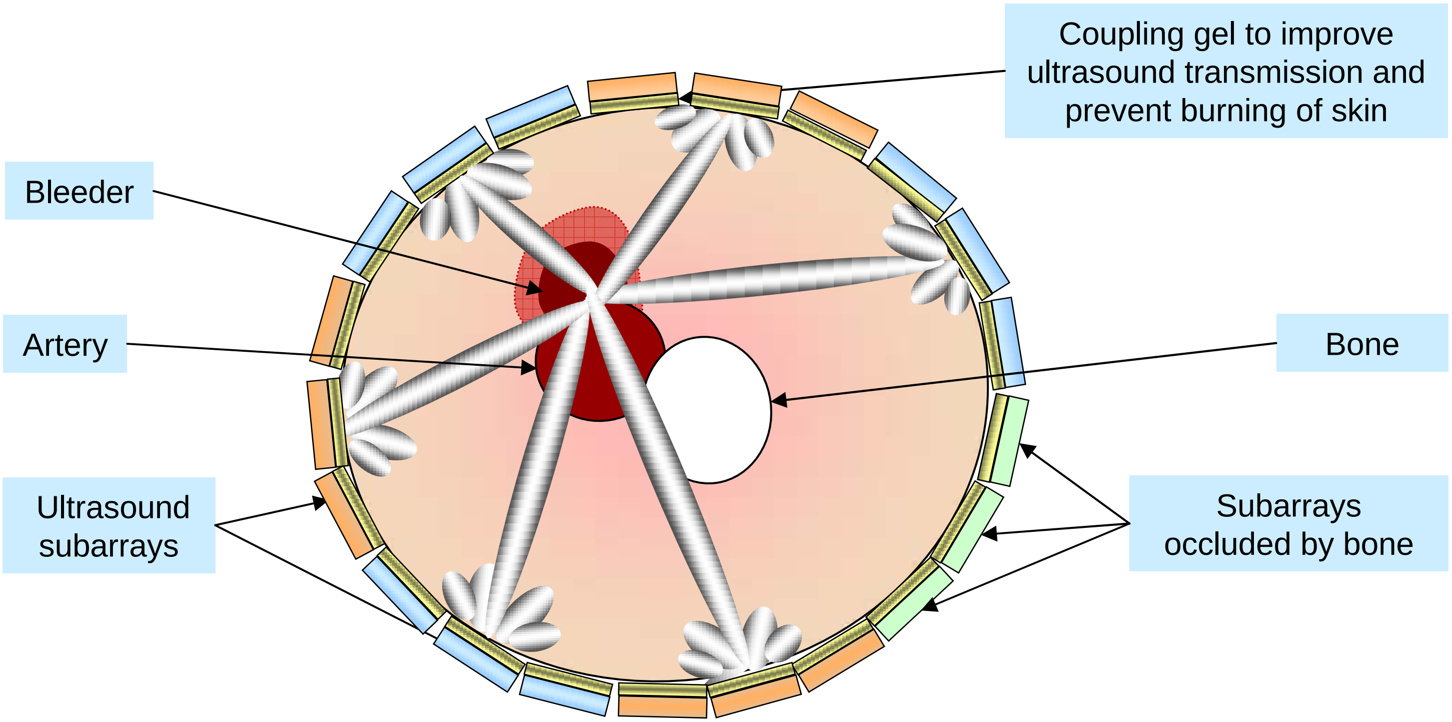


- Subarrays that detect the maximum Doppler shift caused by the bleeder will communicate to adjacent subarrays the bleeder location
- The adjacent subarrays will sweep area to locate and focus onto the bleeder site using traditional phase delay based beam steering

Coagulation

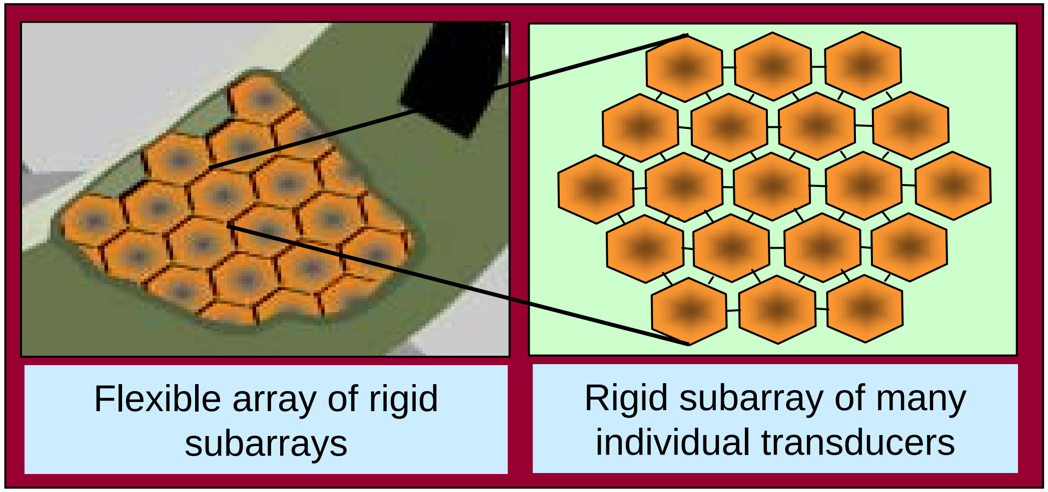
Automated Coagulation of Bleeder

- High intensity focused ultrasound will be used to coagulate bleeder
- The appropriate elements of the array will be fired in unison to achieve rapid coagulation at the site of the bleeder and minimize tissue damage in each individual beam path
- Adjacent subarrays will operate coherently to produce a narrow focused beam



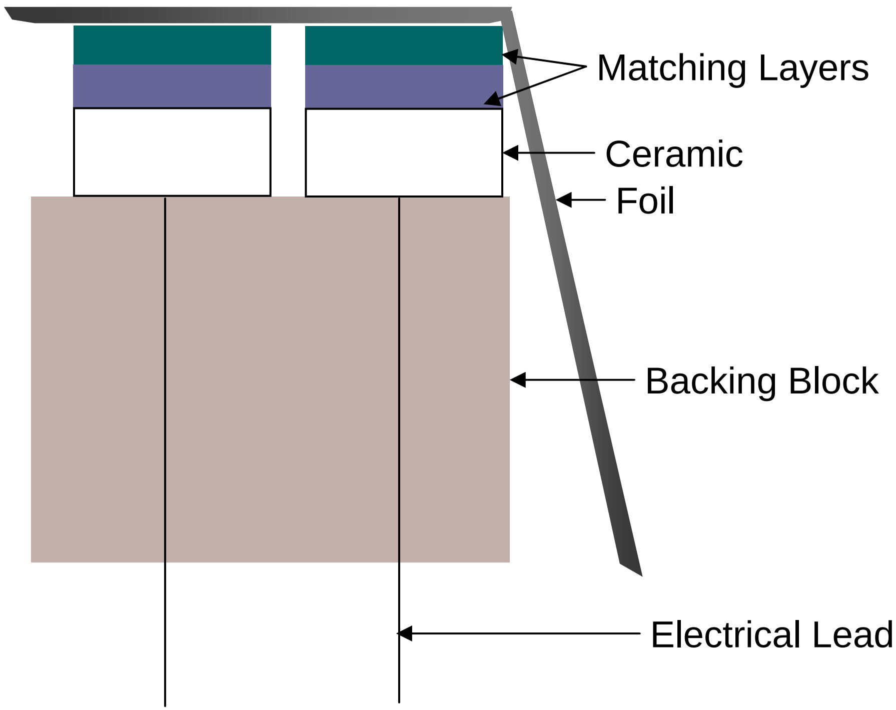
Rigid Subarrays

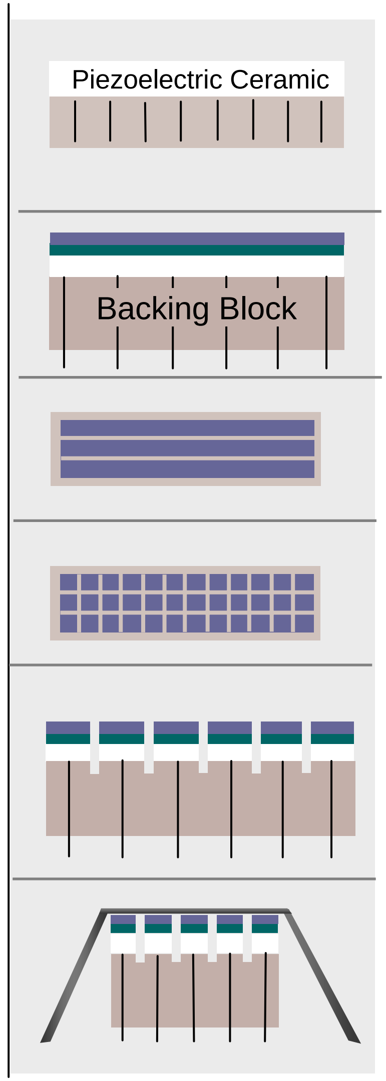
- Focusing of each transducer in the array to the wound area with millimeter or less position accuracy will require:
  - The position of each transducer element to the wound area
  - The position of each transducer element in relation to other transducer elements
- The requirement for a flexible, conformal cuff based array makes the achievement of the focusing requirements difficult
  - Each element in a completely flexible array has no fixed position in relation to each other transducer element
- Subarrays of transducers fixed in position to each other greatly reduce the processing
  - Resulting cuff would consist of a flexible conformal mesh of rigid subarrays



Enabling Technologies from Previous SBIR work

PZT



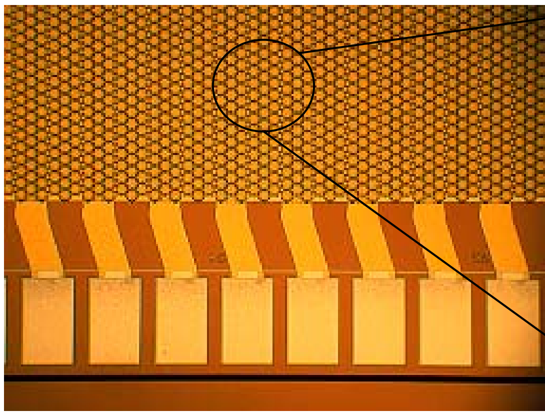


PZT construction

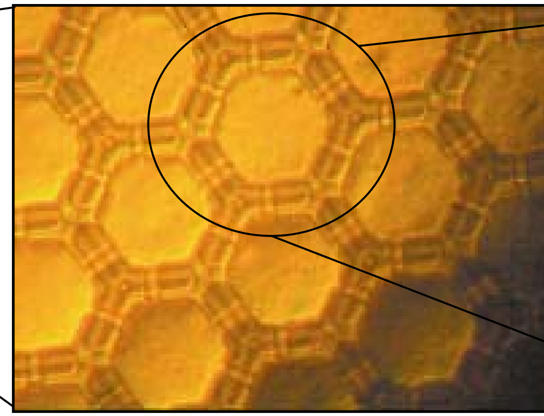
- Mount Piezoelectric Ceramic bound to backing layer imbedded with electrical leads
- Bond Matching Layers
- Front-dice in the X-direction with a diamond blade to create transducers
- Front-dice in the Y-direction
- 0.2mm x 0.2mm x 0.5mm Transducers
- Bond foil

Enabling Technologies from Previous SBIR work (cont.)

Thousands of micromachined silicon drums are formed on a thinned silicon wafer resulting in the formation of a flexible array of ultrasound transducers



Array with thousands of silicon drums



Closeup of silicon drum array

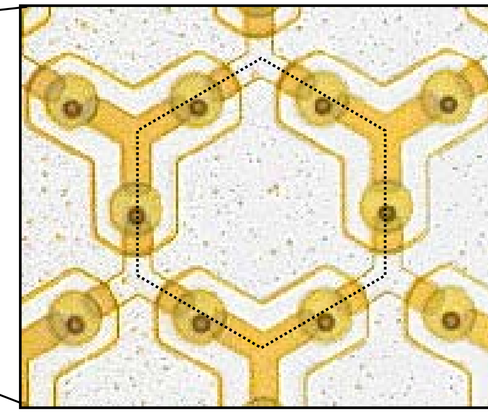
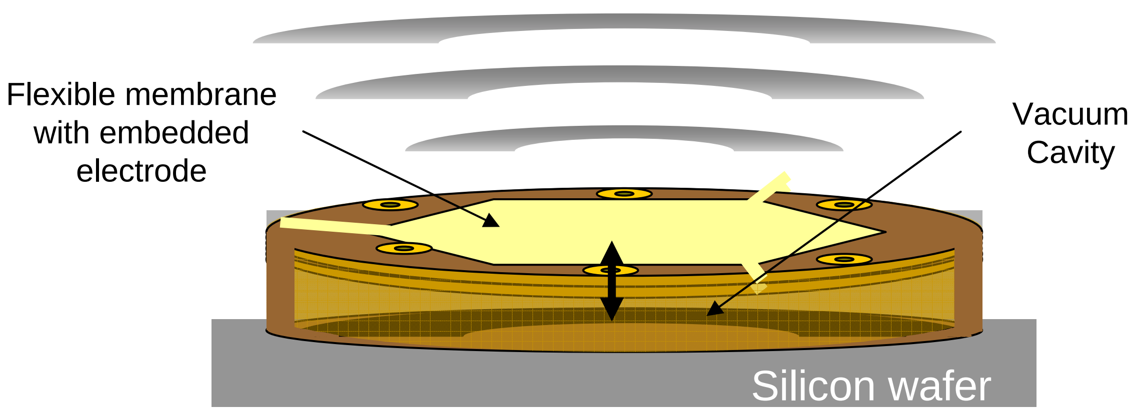


Photo of a single silicon drum



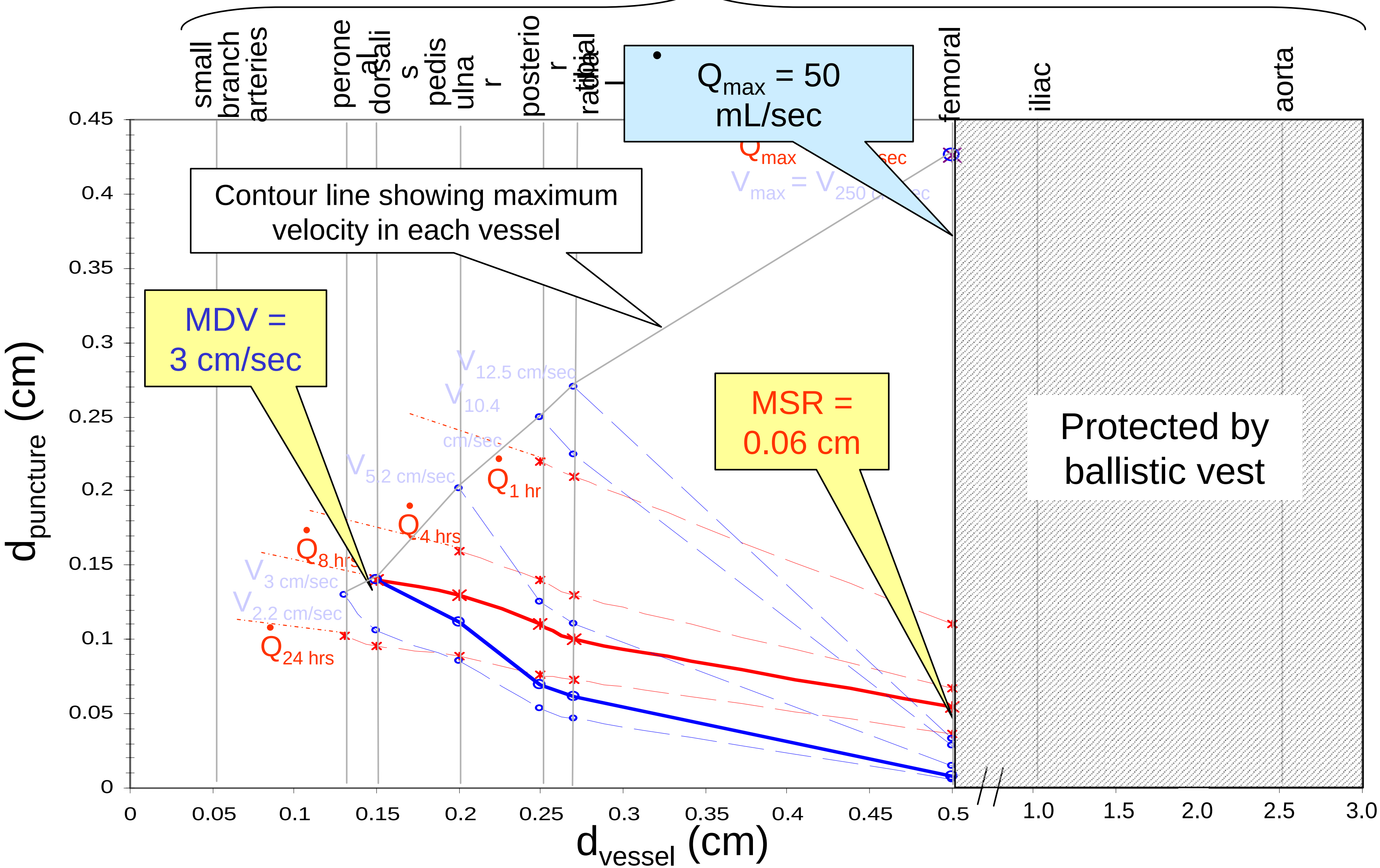
Pictorial cross section

DBAC Specs

Quantity	Definition	Most Challenging Problem	Specification
MDV	Minimum detectable velocity	Slow bleeder in small vessel	3 cm/s
MSR	Minimum structure resolution	Slow bleeder in large vessel	0.06 cm
MPD	Minimum power deposition	Fast bleeder in large vessel	8900 W/cm^2
MTT	Maximum tissue temperature	Damage to surrounding tissue during coagulation	43°C
MCS	Minimum cuff size	Man’s thigh	80 cm x 40 cm
MRC	Minimum radius of curvature	Woman’s bicep	3.75 cm
MDP	Minimum depth penetration	Man’s thigh	12.5 cm
MCW	Maximum cuff weight	Treating burned tissue	3 kg

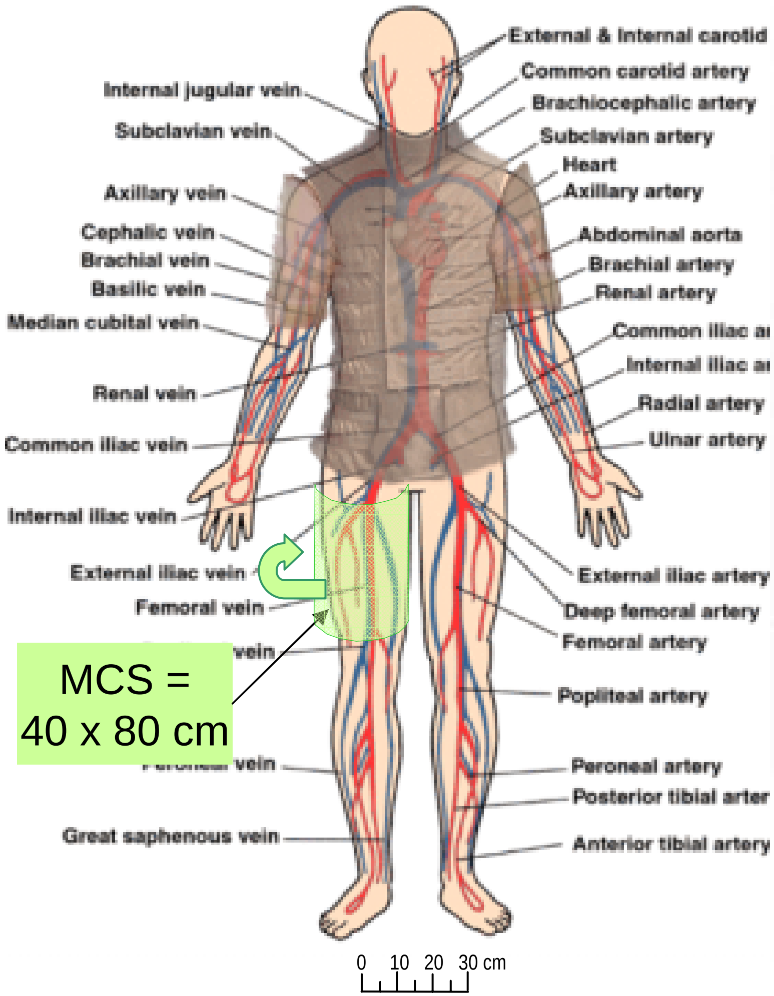
MDV and MSR Specs

Only discrete artery sizes exist (Examples for each vessel size are listed)



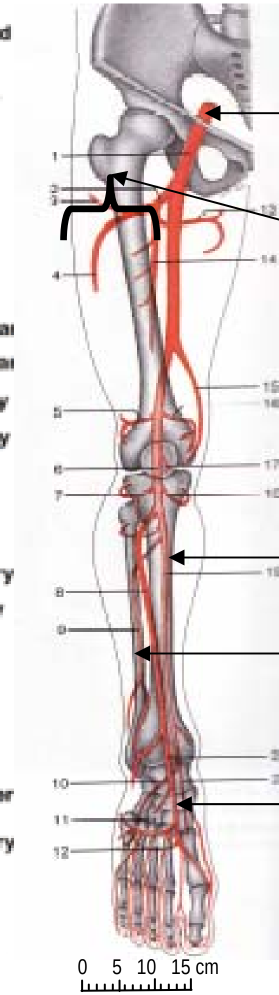
MCS, MDP, and MCR Specs

Ballistic vest



MCS =
40 x 80 cm

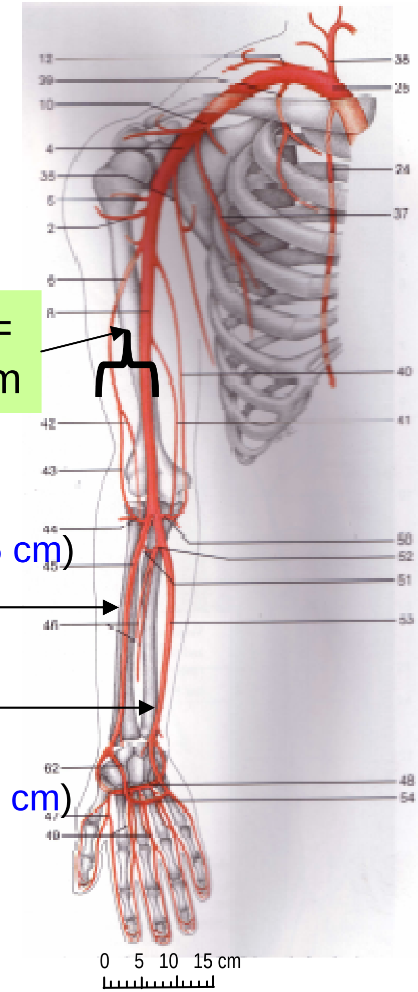
Leg



Femoral artery (0.5 cm)

MDP =
12.5 cm

Arm



MRC =
3.75 cm

Posterior tibial artery (0.25 cm)

Radial artery (0.27 cm)

Peroneal artery (1.3 cm)

Ulnar artery (0.2 cm)

Dorsalis pedis artery (0.15 cm)

Vessel dimensions are exaggerated to show detail

Ballistic vest protects arteries larger than the femoral artery

The effect of punctures in these vessels is shown in slide 3